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HIGH TEMPERATURE THERMOCOUPLE RESEARCH AND DEVELOPMENT PROGRAM

MONTHLY PROGRESS REPORT NUMBER 8
Period 1 January 1964 to 1 February 1964
Contract Number NAS 8-5438
Request Number TP 3-83547

prepared for
GEORGE C. MARSHALL SPACE FLIGHT CENTER
Huntsville, Alabama

work performed by
AUTO-CONTROL LABORATORIES, INC.
5251 West Imperial Highway
Los Angeles, California 90045

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Prepared By: Section Head, Environmental Components

ABSTRACT

This report covers the period 1 January 1964 to 1 February 1964, under Contract NAS 8-5438, which calls for twelve months of research and development of a high temperature thermocouple capable of measuring rocket engine exhaust temperatures in the 3000°C range, under adverse conditions of oxidation, erosion, vibration and shock.

The primary objectives of the program are to advance the state-of-the-art of high temperature thermometry, and to develop an end product suitable for in-flight temperature measurements on the SATURN vehicle.

Work during the current reporting period was directed principally to design, fabrication, and test of the second generation gauges. Three such gauges are scheduled for delivery to N.A.S.A. in February 1964.

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LIST OF ILLUSTRATIONS

SECTION I

SUMMARY

1.0 Period Covered

This report covers the period 1 January 1964 to 1 February 1964.

1.1 Statement of Work

The Contractor shall advance the state-of-the-art of high temperature thermometry and specifically improve the technique of accurately measuring high temperatures by designing, fabricating, testing, and delivering nine (9) thermocouple probes capable of operation in the 3000°C temperature range under adverse conditions of erosion, oxidations and high stress levels for useful period of time. Also, present methods of thermocouple probe fabrication will be modified such that the end product will be suitable for in-flight temperature measurements on the SATURN vehicle.

To accomplish the above objectives, the Contractor shall consider and explore specific R&D efforts as follows:

a. Development of the physical structure of an immersed probe to attain minimum drag and highest resistance to bending and shear forces.

b. Ascertain the best combination of ingredients in the protective coating of the probe to extend the term of oxidation resistance.

c. Determine the best combination of compensated lead wires for use with the immersion type probes.

d. Incorporate latest state-of-the-art materials as potting and sealing elements in the base of the probe.

1.1 Statement of Work Cont....

e. Determine effects of reactions between oxide coatings and tungsten in relation to the emf output.

f. Establishment of rates of erosion for different types of refractory coatings such as tungsten disilicide, carbides and cermets when subjected to high velocity, high temperature gas streams.

1.2 Progress

a. Design

The design of the second generation Type 4735 Gauges was completed.

b. Fabrication

A prototype gauge was fabricated for test and evaluation. Piece parts for the gauges to be delivered were put in work.

c. Calibration Oven

An existing ACL Calibration Oven was modified to accept the Type 4735 Gauges.

SECTION II

PAST PROGRESS

2.0 General

Previous effort was reported in ACL Progress Reports T-1097-1 through T-1097-7.

2.1 Prototype Design and Development

As was previously reported, objectives for the first prototypes were limited to the 4000°F - 4500°F range in the interest of accumulating test data for analysis, the results to be utilized in future design.

A design approach for the prototype gauges was selected, and drawings prepared, detailing means of fabrication and assembly.

Investigations made into fabrication techniques involved in working vapor deposited Tungsten, resulted in improved material handling techniques.

Shock and vibration tests, performed on a prototype mock-up, resulted in a conclusion that the sheath material was intrinsically capable of withstanding the specified shock and vibration requirements.

Samples of various types of compensation lead wires were ordered for test and evaluation.

An evaluation of the SRI calibration tests for ACL Type 4734 gauges was made, resulting in a conclusion that an optimum immersion depth might be in the order of 1-1/2 inches in an isothermal region.

The two Type 4734 gauges tested by N.A.S.A., and returned to ACL were examined, and results of the examination were reported.

2.1 Prototype Design and Development Cont....

A test of a "no-insulation" approach was started, but was aborted due to a failure in the test oven. Such tests were subsequently continued.

Three prototype gauges were delivered to M-ASTR-I, on 17 October 1963, for test and evaluation. Calibrations of this type of gauge indicated a shift in emf output to a higher value than that shown in previous calibrations. The shift was believed due to a spurious emf contributed by the "compensated" lead wires. The curves, however, paralleled the curves taken by Southern Research Institute, as well as those predicted by ACL.

Further tests verified the presence of lead wire errors.

Analyses of form and shock drag loads were made. The results will be considered in future design.

Investigations of oxidation resistant coatings were continued. Accumulated data was reviewed, and tabulated for comparison and reference.

Response tests performed on one Type 4735 gauge yielded response as low as 45 milliseconds from ambient air to boiling water. Lead wire tests resulted in a conclusion that the thermocouple materials should be used in lead extensions for best accuracy. Further investigations of oxidation resistant coatings, and insulators verified the conclusion reached in earlier tests. Design of the second generation gauges was continued.

SECTION III

CURRENT PROGRESS

3.0 General

Effort during the current reporting period was directed principally toward design of the second generation gauges, improvement of the high temperature calibration test set up, and fabrication of a second generation prototype.

3.1 Progress

3.1.1 Second Generation Gauges

Design of the second generation gauges was predicated upon tests of three first generation gauges, as previously reported. Major objectives for improvement were: elimination of lead wire errors, reduction in weight and size, increased integrity of the transitions from the sheath and center conductors to their respective leads, elimination of insulator problems within the sheath, and simplification of sheath fabrication. The sketch of Figure 1 shows details of gauge construction.

3.1.1.1 Body

The body in the second generation gauges is fabricated from series 300 stainless steel. The body length has been reduced to 2.875 inches, and the diameter to .75 inches. The 7/16-20 unf mounting has been retained. All external threads have been eliminated. The internal scheme for retaining the sheath assembly in the body has not been changed. However, the retaining nut has been reduced in length to .50 inch. The threaded connections previously used to make up the body, have been replaced with a weldment between the body proper and a conical stainless steel cap, which replaces the internally threaded cap.

3.1.1.1 Body Cont....

In the final stage of the assembly, the aft portion of the cap is welded to the stainless steel lead wire sheath. The body is thus rendered leak proof, and is highly resistant to environmental stresses.

3.1.1.2 Sheath Assembly

The sheath assembly is essentially the same as previously used in the first generation gauges. The aft portion of the sheath has been shortened to .687 inches. The front end remains the same. As a consequence, the immersion depth will be the same.

3.1.1.3 Insulators

The beryllium oxide insulation in the immersed portion of the gauge has been eliminated, because of the unavailability of a suitable insulator for use at the temperatures of interest. Magnesium oxide double bore insulation is used from the double conical retaining slug back to the lead wire. Compacted magnesium oxide powder is used to fill all voids remaining in the body cavity prior to final assembly. This also provides vibration damping for the lead wires in the transition section.

3.1.1.4 Lead Wire

Tests thus far have clearly indicated the errors introduced in the output of the gauge due to the use of compensated lead wire, where the temperature of the transitions are not controlled within manufacturers recommendations. The possibility of providing gaseous coolant to the body of the gauge has been discussed with M-ASTR-I personnel. However, it is felt that this should be seriously considered only if it proves impossible to utilize other means of eliminating the lead wire error. The most obvious solution to the lead wire problem is to use tungsten and tungsten 26 rhenium. It is entirely practical to bend these materials in wire form if the bend radius is kept large in relation to the wire diameter. The tungsten 26 rhenium is quite ductile and does not become brittle upon temperature cycling.

3.1.1.4 Lead Wire Cont....

The tungsten wire does become brittle, however, the temperature in the lead (aft of the body) is not expected to be high enough to induce embrittlement in the tungsten lead. At the transition between the tungsten lead and the tungsten sheath, the temperature may become quite high. Experience with the Type 4734 and 4735 gauges shows that temperatures may become, during a long run, high enough to melt the brazing material used to effect the transition. A break in continuity would result. In the second generation Type 4735 gauges, ACL expects to use a mechanical bond as the primary joining method. In the prototype constructed for test, three turns of tungsten wire were made around the end of the sheath. As of the present reporting period, this method has yielded good results. Should further mechanical support be required, adequate space is available within the body. Pre-delivery tests are expected to prove the feasibility of the method.

3.1.1.5 Forming Mandrels

The mandrels used to form the first sheaths were made in two pieces. Difficulty was encountered in withdrawing the two-piece mandrels from the sheaths because of adherence between the tungsten and the mild steel of the mandrel. It was necessary, therefore, to etch the steel out with concentrated hydrochloric acid. Although this method works, it is time-consuming and introduces the possibility that a small piece of steel may be left in the tip, near the junction. The present mandrels are one-piece construction. Although the formation appears somewhat more difficult, there is a net saving in time, and the probability of successful mandrel withdrawal is increased. A simple qualitative test then is used to determine whether all steel has been removed. If necessary, any remaining steel can be etched out. Should any steel remain in the sheath, it will liquify with increase in temperature, and, since tungsten is soluble in molten steel, a failure could result.

3.1.2 Calibration Set up

In high temperature tests performed with the ACL gas burner, considerable difficulty has been experienced in obtaining stabilized temperatures.

3.1.2 Calibration Set Up Cont....

Much time has been expended also, in reducing test data to usable form because of uncertainties in making optical measurements due to flame swirls, and in correcting readings for emissivity. ACL has set up, therefore, and plans to use an existing high temperature furnace for future calibrations. The burner will be used only for oxidation tests.

Modification of the ACL high temperature furnace has been made to accommodate the Type 4735 gauges. The furnace is fabricated as follows: An outer shell, made of zirconium oxide coated graphite, surrounds a calibration cavity, which is made of tungsten. A sighting port for optical observation is located opposite the tip of the gauge. A small hole in the bottom of the cavity permits its interior to be flooded with argon gas. The space between the cavity and the shell is also flooded with argon. For viewing the tip, an optically flat quartz viewing port is located in the shell.

The furnace is heated by a heliarc drawn between an electrode and the tungsten cavity. In the past experiments performed with this device, temperatures of 5000°F were reached.

Optical temperature measurements of the gauge tip will be made with a micro-optical pyrometer.

The set up is illustrated in Figure 2 of this report.

SECTION IV

PROGRAM FOR NEXT INTERVAL

4.0 Objectives for the interval 1 February 1964 to 1 March 1964 are:

a. Fabricate second generation gauges.

b. Calibrate and test gauges.

c. Prepare for delivery of gauges.

d. Review progress thus far with M-ASTR-I personnel.

SECTION V

STATEMENT OF MAN HOURS

5.0 Hours by Category

Category	Previous Periods	Current Period	To Date
Engineering	628.0	66.0	694.0
Clerical	115.5	10.0	125.5
Fabrication	622.5	87.0	709.5
Consulting	20.5	-0-	20.5
Drafting	51.0	10.0	61.0

BY RS	DATE [illegible]	SUBJECT 4735 GAUGE,	SHEET NO. 1 OF 1
CHKD. BY	DATE	ASSEMBLY SKETCH	JOB NO. T-1097
		SCALE 1:1	REPORT NO. T-1097-8

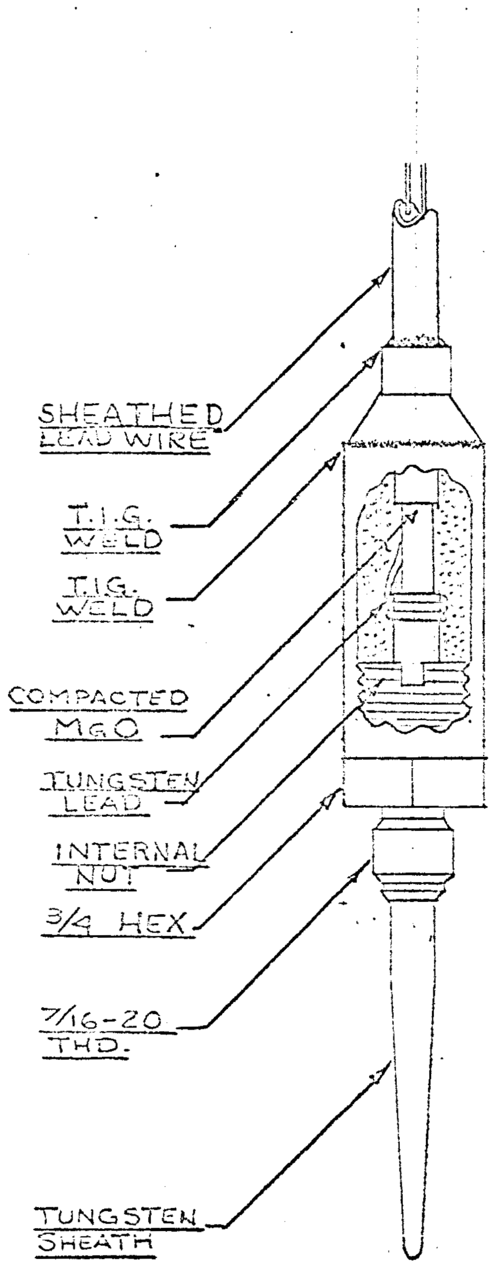

FIG. 1 - TYPE 4735 GAUGE, 2ND GENERATION

BY RS DATE [illegible] SUBJECT CALIBRATION OVEN SKETCH SCALE 1:1

CHKD. BY ...... DATE ......

SHEET NO. 1 OF 1

JOB NO. T-1097

REPORT NO. T-1097-8

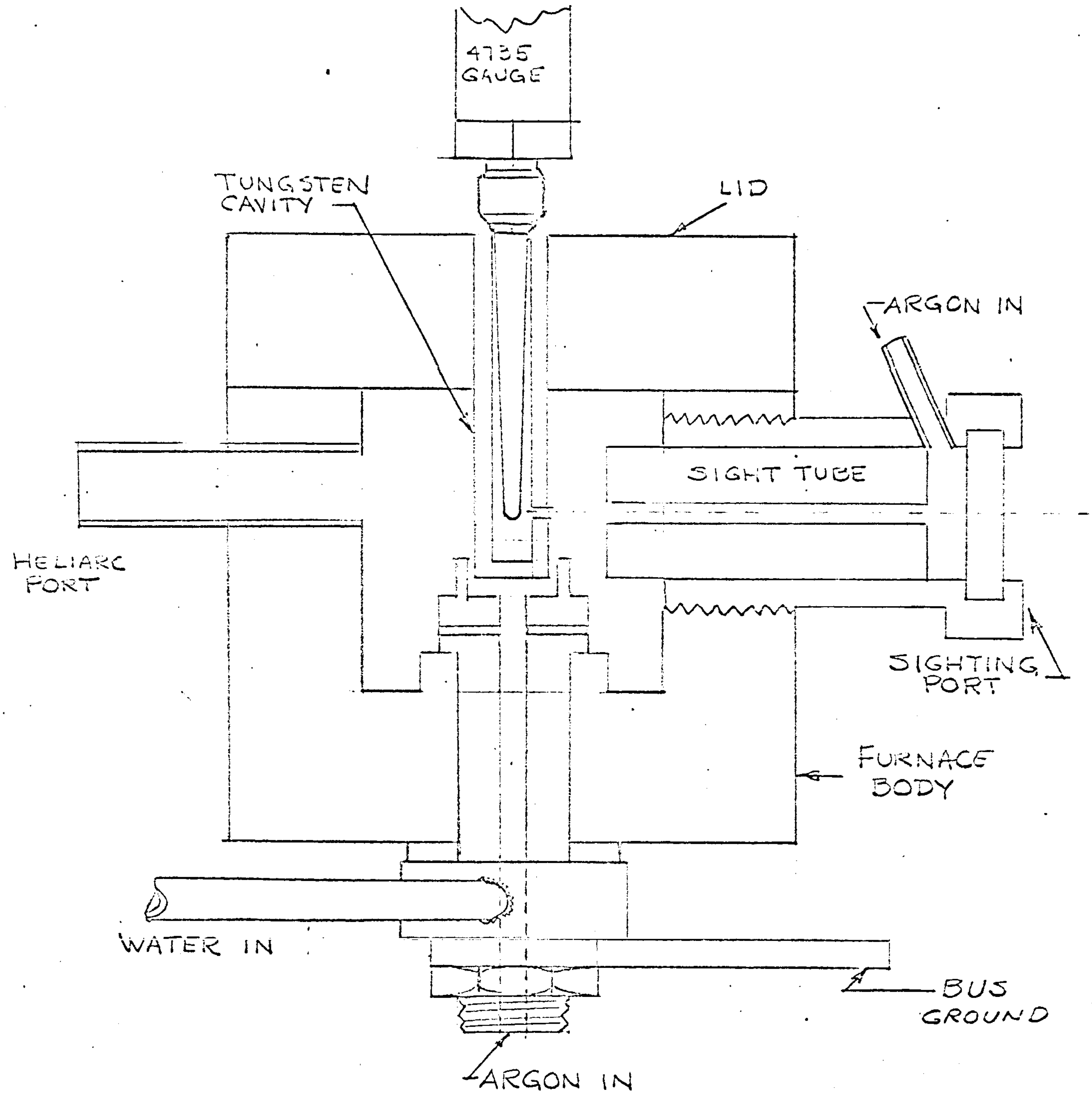

FIG. 2 - CALIBRATION OVEN